

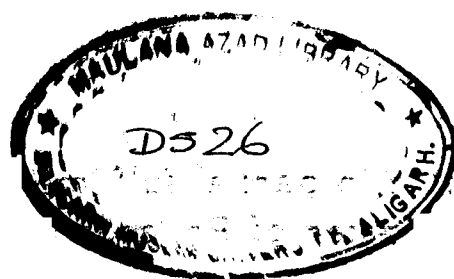


# **STUDIES ON UPTAKE AND TRANSLOCATION OF SYSTEMIC INSECTICIDES IN PLANTS**

**Dissertation submitted in partial fulfilment for the  
Degree of Master of Philosophy  
in  
ZOOLOGY  
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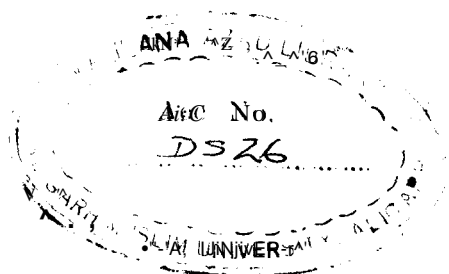
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**C E R T I F I C A T E**

I certify that "STUDIES ON UPTAKE AND TRANSLOCATION OF SYSTEMIC INSECTICIDES IN PLANTS" is the original work of Mr. ASHOK KUMAR GARG and is suitable for submission for the award of the degree of Master of Philosophy of the Aligarh Muslim University, Aligarh. This work has been done by the candidate under our supervision.

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## INTRODUCTION

Insecticides which are absorbed by the plant and translocated to various parts in such quantities as to have insecticidal action are known as "systemic insecticides" (Martin, 1947). Müller (1926) invented the term "Innere Therapie de Pflanze", but Schrader (1947a) called them endotherapeutic insecticides. Some authors have also referred to them as isletoxic, but the term "Systemic" has been widely accepted.

Since 1936, when wheat grown on seleniferous soils was shown to be toxic to aphids (Hard-Karrer and Pees, 1936) the concept of systemic properties of selenium compounds are known. Also other authors such as Speyer (1941), Bennett and Martin (1948) have explored the systemic effect of selenium compounds. David and Gardiner (1953) found systemic properties of sodium fluoroacetate which has been identified as natural toxin in the Gifblaar plant, Dichroetium sycosum (Ripper, 1952). However, with the discovery by Schrader (1947b) concerning the systemic insecticidal properties of certain organophosphorus compounds, during their examination of substances related to war gases, this field of insect control became of practical importance. Their discoveries include the first organophosphorus insecticide (HEP), the first wide-scope organophosphorus insecticide (parathion), the first organic, truly systemic insecticide (Schrader), and the first recognition of the possibilities inherent in this systemic action.

Ripper (1952) classified systemic insecticides into three groups according to their decomposition within the plant : (i) insecticides which are stable during their entire sojourn in the plant e.g. selenium; (ii) compounds which after absorption and translocation are present to

at least 98 per cent in their original form and act as insecticides until they are decomposed by the plants. These are called endolytic insecticides e.g. Schradan and Hanane; (iii) insecticides which are absorbed, translocated and, before they are decomposed, are transported partially or wholly into other toxic substances which also act as insecticides. These are termed as endometatoxic e.g. Systox.

Many compounds with systemic properties are known and it appears probable that any insecticide which is sufficiently water soluble and stable may possess some degree of systemic action. In fact almost all organic insecticides are capable of penetrating into plant tissues and effective systemic action is therefore a matter of degree rather than a specific property.

All the three major groups of organic insecticides viz. Organochlorine, Organophosphates and Carbamates are reported to be having some systemic properties.

The halogen derivatives of the aliphatic hydrocarbons (Organochlorine) are more toxic to insects, microorganisms, and plants than the parent hydrocarbons.

Work by Anderson (1958), Fester et al. (1956), Lichtenstein (1959, 1960) and Lichtenstein and Schulz (1960) indicate that only minute concentrations of organochlorine insecticides are likely to be translocated to the aerial parts of the crops growing in soils containing residues at the levels found in arable soils in England (Wheatley *et al.*, 1962).

The problem of uptake of residues from contaminated soil is of interest in relation to root crops. Terriere and Ingalsbe (1953) indicated the translocation and persistence of residues of DDT, BHC,

toxaphene, chlordane, aldrin and dieldrin in potato and Lichtenstein (1959) observed higher concentration of lindane in the peel than in soil when carrots were grown in a silt loam.

John (1966) found BHC along with other organophosphate insecticides, to be effective in controlling Nephotettix spp. when applied either as soil treatments or as foliar sprays. Rice water application of sevidol (carbaryl 4 per cent G + lindane 4 per cent G) has been adopted as standard practice to control leafhopper and stem borer in some countries (Pathak, 1966). Emphasis has been laid on granular application of carbaryl and lindane (Cantelo and Kovit Kovitvadhi, 1967 and Sriharam and Garg, 1974) to the root zone of the rice plant for the control of rice pests.

Many major industrial products have been developed from the organophosphorus compounds. Most of the systemic compounds are remote organic derivatives of phosphoric or of thiophosphoric acid esters.

Since Hard-Karrer and Peos discovered in 1936 that systemic insecticides are taken up by the roots, it has been verified with other compounds by many others notably Bennett et al. (1949), Martin (1949), Ripper et al. (1950) etc. David (1951) published quantitative data for Schradan (Octamethyl pyrophosphoramide) for bean plant (for blackfly) and Metcalf and Marsh (1952) for citrus trees (for red mite and greenhouse thrips) both using radiotracer method. Similarly West (1951), Nichol (1952) and Hanna et al. (1952) reported the uptake of Hanane by the roots of the cocoa tree and obtained an excellent control of the mealy bug, Pseudococcus nialensis Laing.

John (1966) reported phorate and dimecron to be efficacious as soil treatments and foliar sprays for the control of Nephotettix spp. Phorate was also applied to the root zone of the rice plant for the control of rice pests (Cantelo and Kovit Kovitvadhi, 1967 and Sriharan and Garg, 1974). The uptake, translocation and effectiveness of monocrotophos and dicrotophos against cotton jassid, Aurana (Burana) devastans Dist. was studied by Bhatnagar and Agrawal (1975) in (Pusa Selection-15) variety of cotton.

Derivatives of carbamic acid are widely used as chemical agents for plant protection. Only the esters of N-alkylcarbamic acids have insecticidal properties; the insecticidal activity of esters of N-arylcarbamic acids is slight. All the insecticidal esters of N-alkylcarbamic acids cause inhibition of cholinesterase.

The biological effects of carbamate were recognised by Salway (1912), Stedman (1924) and Stedman and Bayer (1925), Wiesmann (1951). Wiesmann et al. (1951) synthesised one of the first heterocyclic carbamate insecticides, 1-phenyl-3- 5-pyrazolyl N,N-dimethyl carbamate. Other analogs be insecticidal. Kolbeson et al. (1954) investigated the insecticidal activity of a variety of substituted phenyl carbamates and in particular showed that the N-methylcarbamates exhibited maximum toxicity. In succeeding years, the broad insect activity and economic potential were developed as described by Fukuto (1961), Metcalf (1961), O'Brien and Matthysse (1961) and Casida (1963).

Some of the popular carbamate insecticides are Nephthyl N-methylcarbamic acid commonly known as carbaryl or Sevin; 5-5-Dimethyl-dihydroresorcinyl N,N-dimethylcarbamate (dame-ton);

2-Methyl-2-methylthiopropionaldoxime O-N-methylcarbamate (aldicarb);  
2-3-dihydro-2, 2-dimethyl-7-benzofuranyl methylcarbamate (carbofuran)  
etc.

Carbaryl has a broad spectrum of insecticidal activity and low mammalian toxicity (Haynes *et al.*, 1957). Although it has some residual toxicity, it is neither stored in the fat nor is secreted in the milk of dairy cattle (Gyrisco *et al.*, 1960), which permits its application on edible crops and on fodders. Sevidol, a combination of a carbamate-carbaryl and an organochlorine-lindane insecticides in the formulation of 4 : 4 per cent granules, was earlier used as rice-water application and adopted as a standard practice to control leafhopper and stem borer in some countries (Pathak, 1966). It was also applied both as soil treatments, as well as foliar sprays for the control of Nephotettix spp. (John, 1966) and to the root zone for the control of rice pests (Cantelo and Kovit Kovitvadi, 1967 and Sriharan and Garg, 1974). Another potential insecticide, carbofuran proved to be effective in controlling Nephotettix virescens (Distant) when applied to standing water (Kalode *et al.*, 1969), when used in seed treatment and as pretransplant soak (Mitra *et al.*, 1970) and when applied to the root zone of the rice plant (Bowling, 1970 and Sriharan and Garg, 1974). Bhatnagar and Agrawal (1975) studied the uptake, translocation and effectiveness of carbofuran against cotton jassid, AMRASA devastans Distant.

Beside different methods of insecticide application like foliar sprays, bark application, trunk implantation, seed treatment etc., the ability of plants to translocate systemic insecticides from

the roots has been exploited as soil treatment for insect control because (a) a longer persistence of the systemic effect is obtained than with any other method; (b) certain systemic insecticides offer ecological selectivity while foliar application leaves them nonselective (Ripper et al., 1951); (c) it is possible to treat plants before they have a lot of leaf, at a time when the surfaces which could absorb the systemic are confined to the stem (Emery, 1955) and (d) acute toxic hazards during application are reduced as the atomization of the liquid is avoided (Spindler, 1955).

As rice plant is grown under the semi-aquatic condition, emphasis has been laid on granular application of phorate, carbaryl and lindane (Cantelo and Kovit Kovitvadhi, 1967), carbofuran (Bowling, 1970), phorate, carbofuran and sevidol (Sriharan and Garg, 1974) to the root zone of the rice plant for the control of rice pests.

Systemic insecticides which are absorbed by the roots get transported to other parts of the plant growing above the ground through the transpiration stream in xylem vessels to the shoot axis and leaves in the manner similar to the uptake of nutrient salts. Circular application of the soil-root, crown or stem helps in translocation of insecticides to all aerial parts of the plant (Bond, 1953 and Hanna et al., 1955). The halogens increase the insecticidal activity of hydrocarbons in the ascending order Cl, Br. and I. Disubstituted halogens are more active than monosubstitutes.

Lindane poisoning produced marked stimulation of the respiration in Oryzaephilus surinamensis (Lord, 1948). Similarly when 1 µg per cent of lindane was injected into the body of the German Cockroach,

Blattella germanica L., an immediate increase in respiratory rate was observed in it which reached five times the normal after 60 minutes during the period of spasms and slowly declined as paralysis ensued. Lindane injected into Periplaneta americana (L.) at 100<sup>x</sup>/g had little effect on the rate of heart beat but produced an irregularity in pulsation (Orser and Brown, 1951). Bot (1952) has shown that lindane, unlike DDT, has no stimulating effect on motor nerves of Periplaneta americana (L.) or blowfly Calliphora erythrocephala (Meig.), but appears to have a centralized action on the ganglia and requires the presence of an insect reflex arc for the production of tremors and twitching. Tobias et al. (1946) have studied the effect of lindane poisoning on the acetyl choline content of the ventral nerve cord of P. americana (L.) and have found a definite increase in the prostrate stage of poisoning from a normal of 38<sup>x</sup>/g of cord to 57<sup>x</sup>/g for the poisoned roach. DDT poisoning results in a similar increase to about 100<sup>x</sup>/g of cord. Bot (1952) from the results of bioassay techniques with the housefly, has concluded that lindane is carried throughout the bodies of Calliphora erythrocephala (Meig.) and P. americana (L.) primarily in the haemolymph and secondarily in the nerve tissue, and that the material is eliminated by the malpighian tubes.

Both organophosphates and carbamates are toxic by their interference in the normal synaptic transmission of the nerve impulses. Singh (1973) compiled the work on mode of action of organophosphates and carbamates.

According to him toxic phosphoric and carbamic acid esters after penetrating inside the body of insect reach the cholinergic site and inhibit acetyl cholinesterase by blocking its active sites which



are responsible for the hydrolysis of the natural substrate acetylcholine. The acetylcholinesterase inhibition thus lead to an accumulation of acetylcholine at nerve endings, which causes disruption of nervous activity resulting in excitation, paralysis and finally death.

The use of systemic insecticides for the control of insects feeding on the foliage of rice crop is becoming important. The practice of broadcasting granules of sevidol (carbaryl 4 per cent G + lindane 4 per cent G) (Pathak, 1966), phorate (John, 1966, Pathak, 1967) and carbofuran (Kalode *et al.*, 1969 and Pathak, 1970) to paddy water at different growth stages of the rice plant for the control of rice pests particularly Green leafhopper, Neohotettix virescens (Distant) and Brown plant hopper, Nilaparvata lugens Stol. is becoming common. But due to winds and air currents, the granules drift in the paddy field, causes uneven distribution of insecticides. For optimum uptake and translocation of insecticides, the root system of the plant should be in contact with the insecticides (Mitchell, 1959). The importance of placement of granules in the vicinity of the root zone of the rice plant for the control of its pests has been demonstrated by Pathak, 1966; Cantelo *et al.*, 1967, Bowling, 1970; Sriharan and Garg, 1974 and Pathak *et al.*, 1974. As such, knowledge about the movement of insecticide through soil is very essential for its proper distribution and uptake by the plant roots. The movement of diazinon in soil and water was studied by Pathak (1969) by applying the granules to restricted area in the centre of the rice field plot, while the lateral movement of carbofuran applied to flooded rice plant was noted by Bowling (1970). However, information regarding

the movement of insecticides like phorate, carbofuran and sevidol and their uptake by the rice plant is lacking. Therefore, the present studies were undertaken to determine the uptake and movements of these insecticides in lateral and diagonal directions under flooded and non-flooded soil conditions. Investigations were also conducted to study the site of retention of carbofuran, phorate and carbaryl 4 per cent + lindane 4 per cent applied to flooded rice plants under glasshouse conditions. As such the studies have a bearing upon absorption, uptake, translocation and dissipation rates of the insecticides from soil, water and the plants. The presence of toxic quantities of insecticides in rice plant, soil and flood water was recorded on the basis of mortality of green leaf-hopper, Nephotettix virescens (Distant) caged on the transplants.

## REVIEW OF LITERATURE

Bennett (1949) defined a systemic insecticide as a substance which is absorbed and translocated to other parts of the plant, thus rendering untreated areas insecticidal.

Fulton and Mason (1937) produced the first evidence for absorption and translocation of a bulky insecticidal molecule foreign to the plant, when they found that derris applied to the first two leaves of bean plants reduced the attack by the Mexican bean beetle on leaves subsequently produced.

Many compounds with systemic properties are known and it appears probable that any insecticide which is sufficiently water soluble and stable may possess some degree of systemic action. In fact, almost all organic insecticides are capable of penetrating into plant tissues and effective systemic action is therefore a matter of degree rather than a specific property (Ripper, 1952). Thus Schradan and bis (dimethylamino) fluorephosphate (BFPD) are water miscible, whereas para-oxon (a systemic) is soluble to 0.24 per cent and parathion (non systemic) is soluble only about 0.024 per cent (Williams, 1951). Similarly the thiol isomer of Systox<sup>®</sup> (a very effective systemic) is soluble to about 0.2 per cent and the thiono isomer (a weak systemic) to about 0.005 to 0.02 per cent (Ripper, 1952 and Schrader, 1952).

According to Metcalf (1956) the controlling properties of systemic action appear to be : (a) sufficient water solubility to enable the compound to move in the plant sap, (b) ability to

penetrate into plant through roots, leaves and stem, (c) sufficient stability in the plant environment to enable the systemic compound to exert the required degree of residual insecticidal action.

Bennett (1957) also described the efficiency of a systemic insecticide to be dependent on the active participation of the plant in three main processes, namely absorption, translocation and detoxification, where absorption refers to penetration of the cell membrane by the insecticide, translocation to movements from cell to cell and detoxification to all methods encountered in the removal of toxic material from the plant.

Uptake involves those phenomena that account for the movement of systemics from the points of application to the soil or plant into the sites where vascular transport in the phloem or xylem is initiated. Many methods of systemic insecticide application and consequently the suitability of the various plant surfaces for the absorption and uptake of systemics have been emphasized.

#### By seed

The main practical advantage of absorption of insecticides by seeds is that protection against insect attack is afforded during the important seedling stage. However for effective absorption and uptake the seed must be of larger size to absorb sufficient pesticide to protect the resultant plant.

Ivy et al. (1950) did some preliminary tests on seed treatments in which cotton seeds were soaked for two hours in water containing 0.5, 1 and 2 per cent schradan, drained and immediately planted in sand. The plants were uprooted 6, 13 and 35 days later

and infested with mites and aphids. A complete kill of both was obtained with all the treatments.

Chao (1950) found that plants of cotton, pea, various beans and nasturtium grown from seeds soaked in solutions of schradan were successfully protected against attacks by aphids and red spider mite for up to 50 days, and generally the period of protection varied with the weight of the seed. Hopkins *et al.* (1959) obtained significant reduction in the populations of cotton aphids, Anhis gossypii Glover for one growing season by seed furrow treatments with 1 to 3 lbs. thimet (44 per cent) or Bayer 19639 (58 per cent) per acre at the time of planting.

Wilson *et al.* (1960) reported the control of both hessian fly, Phytophaga destructor (Say) and aphids - (i) apple aphid, Rhopalosiphum fitchii (Sand) and (ii) the English grain aphid, Macrosiphum granarium (Kby.) on winter wheat with a seed treatment of 0.5 lb. of phorate per 100 lbs. of seed.

At the time of release of CSR-1 the first commercial hybrid sorghum in India, 10 per cent phorate granules at the rate of 1.5 gm per meter row in the seed furrow at the time of sowing was an usual recommendation, with the care that seed did not come in direct contact with the insecticide as it was adversely affecting the germination (Vedamoorthy *et al.*, 1965). Subsequently disulfoton granules, similarly applied, were found to be equally effective (Anonymous, 1969). Carbefuran at the rate of 3 part per 100 parts of seed, when mixed with the seed on W/W basis, proved to be highly effective against sorghum shootfly, Atherigona varia moccata Rond. up to 20 days after

germination without adversely affecting the germination (Jotwani and Sukhani, 1968). Jotwani (1969) reported almost complete protection of sorghum from shootfly attack with a treatment of 370 g (A.I.) of carbofuran/hectare.

Pathak (1964) reported that thimet, metasytox and n-BHC, when placed at the rate of 8 kg/ha under the furrows of seed bed afforded an effective protection to the plant from rice stem borers and a wide variety of insects upto 30 days after treatment. Carbofuran at 2.67 and 1.30 g of 75 per cent WP per 100 gm of seed and propoxur 20 per cent E.C. at all doses (viz. 4.0 ml, 3.0 ml and 2.0 ml per 100 g of seeds) produced 100 per cent mortality of green leaf-hopper, Nephotettix virescens (Distant) without adversely affecting the germination of seeds of rice variety TN-1 (Mitra et al., 1970). Further both the insecticides produced 100 per cent mortality of leafhoppers on 15 and 30 day old plants within 24 hours at all doses.

Raychoudhuri (1973) reported that an application of 3 per cent carbofuran granules at the rate of 30-35 gm per 100 gm of seeds in the nursery sufficiently checks the population of green leaf-hopper and thus reduces the danger from early infection of tungro virus disease.

#### 11) By leaves

According to Bennett (1957) though the leaves may not be considered normal absorptive areas of the plant, absorption can occur, and it has been found of considerable value. When a systemic insecticide is applied to the foliage of plants a number of processes such as evaporation, absorption and breakdown, can go on simultaneously or sequentially.

The amount lost into the atmosphere by evaporation will depend largely on the vapour pressure of the insecticide and the physical conditions prevailing at the time of application; under conditions of high temperature and air turbulence evaporational losses may be considerable. Heath and Llewellyn (1953) have reported a loss of 50 per cent of applied Schradan from brussel sprouts under field conditions. Thus evaporation can be an extremely important factor in the behaviour of systemic insecticides when applied to the aerial portion of the plant. If the vapour is toxic to insects, then a high initial kill may be obtained by fumigant action on certain crops under favourable conditions, but the loss of material by evaporation reduces the amount available for absorption and for subsequent true systemic action (Bennett, 1957).

Further the amount of any systemic insecticide that is absorbed following leaf application is dependent on a large number of factors which are closely interdependent. Such factors as time, leaf age, leaf-surface, leaf type, conditions of temperature and radiation have been shown to play important roles in controlling the properties of the applied insecticide that is absorbed. The initial effect of these factors is on the amount of insecticide retained per unit area of leaf, but probably their most important effect is that on cell permeability (Bennett, 1957). Bennett and Thomas (1954) while working on variation in absorption of Schradan by bean and chrysanthemum leaves of different ages, found that young leaves absorbed material most and the middle aged leaves least. They also reported lower surface to be about five times as absorptive as the

upper. From the practical point of view, the relative importance of these processes will affect the ultimate behaviour of the material.

Ivy et al. (1950) conducted some greenhouse tests with OMPA and found that the cotton plants received sprays of 1, 2 and 4 lbs. schradan in 3 U.S. gallons of water per acre on the foliage were toxic to the spider mites much sooner than those grown in soil treated with 4, 8 or 16 lbs.

Davis et al. (1953) also conducted a series of tests to study the systemic action of systox (Diethyl-ethyl mercaptoethyl thiophosphate or Trialkyl thiophosphate) on cotton. In one of the tests, systox was diluted at the rates of 10, 20 and 40 c.c. in 2 gallons of water and sprayed on the lower lateral branches of the cotton plants. The mortality of mites on the top of the plant was not highly significant when compared with the spray treatment given to the entire plant.

Chachoria (1972) however reported that the foliage applications of some of the systemic insecticides have in general failed to provide acceptable level of control of sorghum shootfly, Atherigona varia macgata Rond. under conditions of heavy shootfly infestation.

In rice crop Pathak (1964) reported 100 per cent increase in yields, as against untreated check of stem-borer attack, with foliar applications of  $\alpha$ -BHC repeated at 10-day intervals. Further, it was emphasized that the use of  $\alpha$ -BHC as a systemic insecticide offers a great advantage over the conventional foliar applications. Murthy and Khan (1958) found a single spray of 0.1 per cent Metasystox at the time of emergence of the flag leaf in rice to be effective



against the stem-borer, Trypoxys inaequalis (Walker) during its adult and larval stages. Nagaraja Rao (1958) tested 0.075 per cent Pestox, 0.075 per cent Systox along with 0.05 per cent Polidol sprays 10 days before uprooting the seedlings from the nursery, 20 days after transplanting, and <sup>at</sup> the shoot-blade stage (boot-leaf stage i.e. about 15 to 20 days before panicle emergence) and reported that folidol and systox were potentially systemic and resulted in good control of borers, followed by an increase in yield.

#### iii) By bark or basal trunk

Application of systemics to the basal trunk or to the bark is being mostly applied in case of large trees. Bond (1953) found this method more efficient than root absorption with dimefox on coffee. Metcalf and March (1952) demonstrated that the leaves of sour orange seedlings accumulated Schradan at the same rate from bark application as from root treatment, even though the dosage applied to the bark was only 0.03 of that used with the roots. Bond (1953) also reported better absorption of dimefox when the material was applied to the exposed cambium of coffee trees, thus indicating that the outer epidermal or collenchyma cells are able to absorb the lipid soluble materials more efficiently. The work of de Pietri-Tonelli (1965) and co-workers with dimethoate in a variety of trees has contributed much of the uptake of systemics from trunk applications, and the insecticide was traced through the periderm of the trunk into the cortical parenchyma. It moved into the phloem and outer xylem by radial cell to cell transfer. The dosages of insecticides required for a certain level of pest control in a tree applied via the trunk frequently are 1/10 to 1/5th those required in

the soil (Norris, 1965). Banding of the circumference of the basal trunk with chemical generally will yield the most uniform distribution of the pesticide in the tree (de Pietri-Tonelli *et al.*, 1962 and Coppel and Norris, 1966). The physical ease of placing a systemic on the basal trunk commonly surpasses that of making soil treatments to the root systems, especially of large trees (de Pietri-Tonelli *et al.*, 1962 and Coppel and Norris, 1966). The chemical applied to the trunk also is not as dependent upon moisture for uptake into the plant as with soil treatments. Great accuracies in dosage are possible via the trunk than through the soil (Norris, 1965 and de Pietri-Tonelli *et al.*, 1962). This route according to Norris (1967) also allows a more accurate timing of the necessary concentration in the tree.

Bhatnagar and Agrawal (1975) studied the uptake and translocation of carbofuran, monocrotophos and dicrotophos by wrapping the stem of 60 day old cotton plants at varied lengths from soil level, with cotton impregnated with 1 ml of 1.0 per cent freshly prepared insecticide solution. It was then found that irrespective of the length of stem treated, the uptake of toxicants, on the basis of mortality of cotton jassid, Amrasca devastans Dist., continued to increase upto 7 days in case of monocrotophos and upto 3 days in the case of dicrotophos and carbofuran. The uptake of monocrotophos was recorded higher followed by dicrotophos and carbofuran.

Sriharam and Garg (1974) while working on the effectiveness of granular placements of systemic insecticides for the control of rice green leaf-hopper, Nephotettix virescens (Distant) under glasshouse conditions, observed slow absorption of carbofuran, phorate and sevidol

when these were placed either in water confined to 2.5 cm of the lower leaf sheath separated by soil with a 10 mm layer of paraffin or when applied as a paste on the lower portion of leaf sheath. Most rapid absorption of these insecticides were however recorded when placed in the soil near the root zone and flooded with 2.5 cm level of water.

#### iv) By roots

This is the normal channel of absorption of water and minerals into a plant from the surrounding media, taking place through the root hairs, which are specialized epidermal cells. Mitra et al. (1970) reported pretransplant soaking of rice seedlings for 36 hours in carbofuran solutions of 8.0 and 16.0 g of 75 per cent W.P. per 4.6 litre of water to be non-phytotoxic and caused 100 per cent mortality of rice green leaf-hopper, Nephotettix virescens (Distant.) within 6 hours after release on 15 and 30 day old transplants. Among the different formulations of systemic insecticides, granules are being extensively used in the soil for the control of wide variety both, foliage feeding and plant sap sucking insects, infesting various crops. This is due to various reasons viz. ease of application, less number of applications, less operational hazards to operator, effectiveness for longer duration, effectiveness against those sucking pests which remain concealed in convolutions of leaf folds, leaf sheaths and against stem borers. For the effective application of systemic insecticides to the roots of plants, the most important factor is the contact between the roots and the insecticides. The absorption of insecticides by roots from various media is shown greatest from solution, less from sand and least from soil.

Water solubility of insecticides appears to influence the persistence of an insecticide in soil by resisting or facilitating leaching as it also seems to be linked with the ease with which chemicals are absorbed (Edward, 1966). Thus the most persistent insecticide in soil DDT has been quoted as the least water soluble (0.0002 ppm) organic substance known (Filmer and Smith, 1944) while other commonly used chlorinated hydrocarbon insecticides are in order dieldrin (<0.1 ppm) aldrin (<0.05 ppm) and lindane (10 ppm) corresponding roughly with the order of their persistence. According to Lichtenstein and Schulz (1964) moisture enhances the release of volatile insecticides from the soil particles and also influences their breakdown through hydrolysis.

Lichtenstein (1958) found that parathion leached through soil more readily than lindane which is less water soluble. Lichtenstein and Schulz (1965) reported more residue in crops (potato, radishes and carrots) grown on heptachlor-treated soils than in those from aldrin contaminated soil pots. Sriharan and Garg (1974) also reported that beside the site<sup>of</sup> application of granules of systemic insecticides, adequate water supply is necessary to achieve effective control of rice pests.

David (1951, 1952) found that more methidathion and dimethoate absorbed from sand than from soil and, it has been shown, that while dimethoate is absorbed freely from solution, the absorption from sand and humus containing soils is a slower process and is effected only up to a certain limited concentration, which differs for each type of soil (Teitz, 1954). Getzin and Chapman (1960) observed that within an hour of treatment, sandy, silt loam and muck soils had lost 25, 20 and 18

per cent respectively of radioactive thimet (phorate) applied, but after this, initial loss very little or no volatilization occurred. Zaki and Reynolds (1961) conducted leaching experiments with phorate, dimeton and dimethoate and concluded that the insecticides distributed more quickly in sandy soil than others. Gupta and Mishra (1971) reported 80, 83 and 86 per cent recovery of carbaryl and 88, 94 and 95 per cent recovery of dimethoate from clay loam, loam and sand respectively.

Another important factor may be the prevailing temperature. Metcalf *et al.* (1959) reported that the rates of oxidation of Di-syston metabolites in isolated leaves were accelerated by increased temperature between 2.2° and 37.7°C and from the Arrhenius energy activation of 10,200 calories per mole, it was determined that the rate of oxidation of Di-syston sulfoxide increased about 1.9 times for each 10°C rise in temperature.

Terriere and Ingalsbe (1953) studied the translocation and persistence of residues of DDT, BHC, toxaphene, chlordane, aldrin and dieldrin by using a mosquito larvae bioassay method. Heptachlor was found to be deposited in potato tubers grown in soil treated the same year; aldrin and EPN showed evidence of deposition as long as 2 years, and BHC, chlordane and dieldrin were found in potatoes 3 years after the soil was treated.

Thimet (44 per cent G) and Bayer 19693 (50 per cent G) applied at 10, 20 and 30 lbs. per acre as a side dressing significantly decreased the numbers of cotton aphids (*Aphis gossypii* Glover) for 15 months (Hopkins *et al.*, 1959). Wilson *et al.* (1960) reported the control of spring brood of hessianfly on wheat by granulated 10 per cent

phorate broadcast at the rate of 1.75 lbs. of toxicant per acre.

### Translocation :

Normally translocation implies the movement of materials in the phloem or xylem conducting tissues of the plant. The systemic insecticides depend for their efficiency on the extent, both in amount and direction of their distribution through the plant. It is also expected that the process of translocation will vary according to the insecticide and the site of absorption. Thus Ripper *et al.* (1950) stated that aphids on the upper parts of the plants were killed when the roots were irrigated with a solution of schradan. Application to the upper surface of the leaves killed aphids feeding on the lower surface and spraying lower leaves killed aphids on the flowers, tips and remaining leaves. Further, Metcalf and March (1952) pointed out that the type of translocation is influenced by the way of entry. When schradan was absorbed through the bark of the trunk, it was translocated to the leaves, while by uptake through the roots, median leaves attained the highest concentration of schradan.

1) Translocation after seed absorption : Following absorption by seeds it was expected that cotyledons act as reservoir of insecticides as well as plant food and parallel transportation to areas of new growth (Bennett, 1957). Chao (1950) showed that toxicity of schradan to aphids was first lost by the young leaves at the top of the plant demonstrating that the chemical was not evenly distributed but tended to remain in those parts to which it was originally translocated from the cotyledons. David and Gardiner (1955) found that

the distribution of the thiol isomer of dimeton in the plant was fairly uniform after seed treatment and that translocation of insecticide occurred to the aerial part of the plant, some directly from the cotyledon and the rest from the roots after having passed into the soil and been reabsorbed.

11) Translocation after leaf-absorption : The amount and direction appear to be more variable as compared to root absorption although the actual amount of the insecticide translocated after leaf absorption is not much (Bennett, 1957). Dicker (1950) stated that good aphid control was obtained on untreated leaves by dipping few leaves of potted plants in solution of 0.094 per cent schradan. Lickerish (1951) pointed out that the plant surface should be sprayed as completely as possible, rather than a small part of the leaves only, so as to shorten the required translocation path within plant. Thomas and Bennett (1954) found that the amount and direction varied according to the foliage zone treated, more movement occurring from older to younger leaves than in the reverse direction, although small quantities of undecomposed schradan were detected in leaves below those treated in apples and chrysanthemum. They suggested from results obtained by ringing apple root stocks above and below treated leaves that limited movement of schradan and its decomposition products occurred in an upward direction in xylem, but the majority of movement was in phloem and downward movement was exclusively in this tissue. This suggestion of movement of schradan in phloem tissue was supported by its presence in the nectar secretion of some plants (Glynn-Jones and Thomas, 1953). Casida and Allen (1952) studied the absorption and translocation of

several insecticides by plants and found that aystox was translocated through the actively growing plants after the exposure of the roots, seeds or cut stem and repeated application to the upper leaves resulted in translocation from leaf to leaf, rendering the plants toxic to aphids and mites. Thomas and Bennett (1954) observed that plants kept in darkness before and after spraying insecticides show very slight translocation suggesting thereby that light is an important factor in promoting translocation. The effect of light is probably not direct but depends on the fact that in some plants active photosynthesis, and in others the products of this process, are necessary for translocation of insecticide (Bennett, 1957). The concentration of insecticide to leaf periphery suggests that movement in xylem is much easier than in phloem. In cotton translocation of demeton occurred only in the xylem, and although movement was traced in both directions, it was most rapid towards the apex (Ahmed et al., 1954). Teitz (1954) found that a certain percentage of the active ingredient was translocated so that the more extensive the treatment of the leaves, the greater the amount translocated. Concentrations of demeton were found in epidermal cells and the cells of the connecting bundle parenchyma, and it was suggested that when the concentration in these parenchyma cells rises beyond a certain limit, the insecticide is flushed passively into the phloem and from there, on a small scale into xylem; in Peperomia sp. twice as much was transported in phloem as in xylem.

### iii) Translocation after bark absorption : Hedding (1953)

found that after bark absorption of demeton by lemon plants, the



initial translocation took place in the phloem, although diffusion into and transport in the xylem took place later. The rate of downward movement was 2.5 cm/hr and of upward movement was 10 cm/hr. Little lateral movement of dimethoate was shown to occur following its implantation into the trunks of cacao trees although upward movement in xylem occurred quite freely (Hanna *et al.*, 1955). Ridgway *et al.* (1965) found the highest concentration of toxic metabolites of DDT in the older leaves and treated portion of cotton stem. Bhatnagar and Agrawal (1975) observed that with the increase in the length of the treated stem there was a corresponding increase in the amount of insecticide translocated to leaves. On the 3rd day they found the translocation of dicofol 60.9 per cent higher in 4 cm treated stem compared to 1 cm. In monocrotophos and carbofuran, however, the additional translocation of 3rd day in 4 cm was 24.8 and 30.9 per cent, respectively over the 1 cm application. Further, the translocation rate, irrespective of the length of stem treated, was recorded higher towards the apical leaves than towards the bottom leaves although carbofuran was only seen to be actively translocated towards the lower side also.

iv) Translocation after root absorption : Translocation to the aerial parts of the plant from the root occurs, often quite rapidly. The accumulation could be expected to occur in the areas of most active transpiration as it is assumed by many workers that this is a passive movement in the transpiration stream (Bennett, 1957). Bennett (1949) found the rate of translocation of dimethoate in willow following absorption by the roots to be about 11 cm/hr and suggested that translocation occurred in the xylem tissue, as restriction of transpiration of the

leaf either prevented the insecticide reaching or being given off by the leaf. Wedding and Metcalf (1952) found that the rate of movement of schradan in the stem of bush bean, Phaseolus vulgaris varied from 17 to 98 cm/hr with the majority at 20 cm/hr and that the translocated material tended to accumulate more rapidly in the younger tissues of both stem and leaf. Teitz (1954) while working on translocation of demeton in Vicia faba and Salix viminalis concluded that the insecticide moved primarily in the xylem of the shoot axis and the leaves and accumulated in the peripheral zones of leaves as a result of the blind termination of the transpiration stream in the parenchymal cells. Limited lateral diffusion from xylem to phloem occurred, but the concentration in the phloem parenchyma increased only slowly.

Metcalf and March (1952) found that the distribution of labelled schradan and phosphoric acid was uniform throughout the lemon plant although schradan accumulated more in the median leaves while phosphoric acid was more concentrated in the basal ones indicating that the translocation, which would appear likely to occur in xylem tissue, can be selective and is not entirely dependent on the amount of transpiration occurring from a particular area. Metcalf *et al.* (1954) found that the translocation of the thiono isomer of demeton in lemon seedlings was similar in amount and direction to that of schradan though it tended to accumulate rather more in terminal leaves.

Ivy *et al.* (1950) reported that when schradan was added at the rate of 1.2 to 76.8 parts per million to a nutrient solution in which cotton seedlings were grown for a fortnight, after which they were transferred to untreated solutions and infested with aphids and

mites, all the aphids died in 3 days on plants treated with 38.4 ppm and all the mites in 2 days on those treated with 9.6 ppm. Fjeldalen (1930) stated that the systemic toxicity of aystox by the absorption through the roots was less effective on mature plants. On young growing plants, the leaves became toxic to aphids and mites when roots were exposed in it. Ridgway et al. (1965) while working on the translocation of radioactive D<sub>1</sub>-ayston in cotton plant found more radioactivity accumulated in leaves with lesser amounts in terminals, stems, squares and bolls.

Koshihara and Okamoto (1957) were the first to show that 3 per cent BHC dust or 3 per cent lindane dust at the rate of 90 to 180 kg/ha when applied to paddy soil at puddling (before transplantation) was strong enough to control insect damage to the rice crop. Okamoto and Koshihara (1959) inferred that the effect of  $\alpha$ -BHC in paddy soil had resulted from the absorption and translocation of the toxicant through the root.

Ishii and Hirano (1962) confirmed by using radiotracer technique that the radioactive  $\alpha$ -BHC was absorbed from the roots of rice plant and translocated upward to the stem and the leaf through the vascular bundles. They pointed out that when  $\alpha$ -BHC was dissolved in water it was absorbed by the root and then translocated to the rice stem and leaf; it also crept up along the leaf sheath by capillary action. They considered that when  $\alpha$ -BHC was applied to irrigation water its main route was via the leaf-sheath, surfaces rather than via the root systems and through translocation streams. Tsukumo and Suzuki (1962) concluded that the rice plant can absorb  $\alpha$ -BHC through its root

system and translocate it to the other parts. Masuda and Fukuda (1962) attempted to determine the amount of *p*-BHC translocated from treated soil to rice plant by a bioassay using the azuki bean weevil. A considerable amount of insecticidal toxicant almost as much as that in the leaf sheath or root, was detected even in the leaf blade. Saito (1964) however commented that generally, *p*-BHC is not included in the category of systemic insecticides but the translocation or absorption of *p*-BHC in the rice plant is a special case, compared with other plants.

Sevin (1-naphthyl N-methylcarbamate) is being extensively applied to control rice leaf hoppers. Masuda and Fukuda (1961) observed that sevin exhibits systemic action and transfers from the treated soil to the plant grown in it. In further tests by Fukuda and Masuda (1965) this compound accumulated in greater amounts in the leaf blade than in the leaf sheath or root. Masuda *et al.* (1963) considered that the radioactive materials dissolved in the surface water may have been absorbed into the plant tissues through the lower part of the leaf sheath and translocated to the leaf blade, probably along the plant sap stream.

Carbofuran, 2,3-dihydro 2,2-dimethylbenzofuran-7-yl methylcarbamate is a systemic insecticide with acaricidal and nematocidal activity as well, and rapidly metabolizes both in plants and animals. Carbofuran granules incorporated as a pretransplant soil treatment at rates from 0.25 to 1.00 lb. a.i.n./acre resulted in mortality of adults of *Lissorhynchus gravenhillus* Kuschel, the rice water weevil in greenhouse tests upto 6 weeks. The toxicant was reported to be

translocated to the rice leaves and mortality resulted from feeding (Donoso-Lopez and Grigarick, 1969). Carbofuran was also reported to be the most effective systemic insecticide from IRRI which caused more than 70 per cent mortality in both; brown plant hopper and green leafhopper of rice, upto 20 days after each application when it was applied to the paddy water at the rate of 2 kg a.i./ha (Pathak, 1971).

In 1964, IRRI reported that dimecron,  $\alpha$ -BHC, sevin and thimet (phorate) when applied at the rate of 3 kg a.i./ha to the soil in clay pots containing test plants, 90 per cent kill was recorded with dimecron in 4 hours after caging while with thimet and sevin this level of mortality reached 8 hrs. after caging. Plants treated with thimet had longest residual effect (25 days), sevin was effective upto 15-20 days while dimecron had a low residual effect beyond 5 days after treatment. John (1965) observed 40 per cent kill of rice leafhopper, Nephotettix spp. upto 25-30 days with thimet applied to the soil around the plants at the rate of 3 kg a.i./ha 3 days after transplanting.

Cantelo and Kovit Kovitvadh (1967) observed excellent control of rice gall midge, Pachydiplosis oryzae (Wood-Mason) with phorate granules applied to the flooded rice field at the rate of 3.92 kg/ha and presumed that the active ingredient was absorbed by the roots or basal area of the rice plant and was translocated to the buds.

Pathak (1967) observed no apparent phytotoxicity on rice crop at 50 days after transplanting when single application of lindane or metasystox or phorate were applied to the paddy water even upto

8 kg/ha. All insecticides were reported to control the rice stem borer and thus increasing the rice yields significantly. Phorate plots produced the highest yield, but lindane was having the longest effective residual period for stem borer control. Further, when these insecticides were applied to the soil surface or to the paddy water the compound was absorbed and translocated in the plant system where it acted as a systemic, moved by capillary action between the leaf sheath and stem, and killed the stem borer moths and a wide variety of other insects by fumigation.

## MATERIALS AND METHODS

### Systemic insecticides

For the present studies insecticides, phorate (thimet) available in 10 per cent granules, carbofuran (furanon) also in 10 per cent granules and sevidel (formulation of carbaryl 4 per cent G + lindane 4 per cent G) were used.

The uptake and translocation of these systemic insecticides was studied in rice seedlings of IR-8 variety. These seedlings were raised in a nursery prepared in clay pots. 4-leaf stage plants were always used for the purpose.

The effectiveness of the insecticides was studied on the basis of mortality of green leaf-hopper, Nephotettix virescens (Distant) caged on the treated plants. For this a large number of leaf-hoppers were reared in the glasshouse on rice plants of Taichung Native-1 variety under optimum temperature and humidity.

### Rearing cages

Adult leaf-hoppers were kept in cages (91 cm in length, 45 cm in width and 54 cm in height) covered on the top and on two side with alkathene netting (60 mesh). The floor of the cage was made of asbestos sheet. The front side with glass screen was always kept towards sunshine while the back side with a wooden door was kept opposite to light. The door was also provided with view glasses. Freshly potted transplants of about one month old rice seedlings were regularly supplied at weekly intervals with proper watering, twice a day.

The leaf-hoppers oviposit in the parenchymatous tissue of mid rib and leaf sheath. On hatching the young nymphs were transferred on young rice transplants with succulent leaves in other cages (size : 45 cm in length, 45 cm in width and 94 cm in height). After 2 to 3 weeks, the nymphs finally moult into adults, which were taken for the present studies.

#### A. Experiments on the uptake, translocation and movements of insecticides.

For the studies on uptake, translocation, and movements of phorate, carbofuran and sevidol in different directions a special type of experimental cage was fabricated which suits to keep the leaf-hoppers on the rice seedlings for longer durations, with least amount of injury to the plant.

#### Description and construction of the cage

The cage (Fig. 1) was made of rectangular wooden frame, the dimensions being 30 cm in height, 7.5 cm in length and breadth and 2 cm in thickness. The top and two sides of the cage were covered with thin nylon netting (60 mesh) to facilitate proper aeration. The other two sides were provided with the reusable glass observation screens which give proper illumination and facilitates in obtaining data. A wide hole (1 cm) was made on one side wall of the nylon netting for introduction of the insects. The open bottom (7.5 cm x 7.5 cm) rests on a 5 cm x 5 cm base made of aluminium angles. The base can be inserted into the soil giving firm support to the main body of the cage and checking any gap for insects' escape. The cage is set up on the plant by placing the plant's stem and leaves

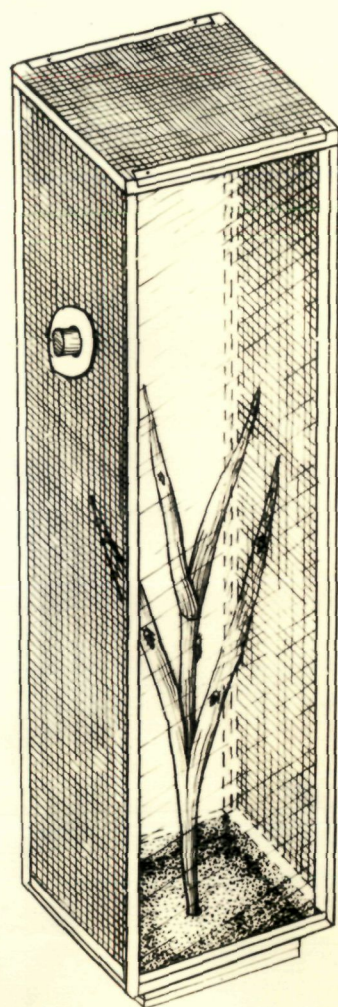


in position through the open bottom and made to stand erect by inserting the base into the soil. Water is supplied through the nylon netting on the sides. This cage because of its maneuverability and transparency helps in obtaining data and changing the subject material. The transparent glass permits regular check up of the experimental subjects, thereby cage removal is not found necessary. Aeration and illumination of the enclosed environment is as natural as circumstances permit.

1. Uptake and translocation of insecticides : In order to study the uptake (absorption) of the insecticides, tests were conducted under two different soil moisture conditions; (i) flooded soil with 2.5 cm water level and (ii) non-flooded soil but with sufficient moisture. These experiments were carried in three different sets. In each set there were five plastic pots (size 12.5 cm x 12.5 cm x 14 cm in height). In each pot strained alluvial soil was filled to a level of 11.5 cm and 4 leaf stage rice plants of IR-8 variety were transplanted. Four pots in each set were separately treated with granules of phorate, carbofuran and sevidol at the rate of 2 kg a.i./ha and one pot was kept as untreated check. Ten leaf-hoppers per plant were then caged and the mortality of leaf-hoppers at different time intervals was recorded (Table 2).

2. Movements of insecticides - a) Lateral direction: This too was studied in flooded and non-flooded soil moisture conditions.

The experiment was conducted using randomized block design with four blocks and equal number of observations per treatment (insecticide). Within a block there were 4 zinc trays (49.5 cm x 35 cm x 25 cm). These were filled with 20 cm of strained alluvial soil.



**Fig 1** Experimental unit showing a single  
plant caged with Green leaf hoppers (IO)



Water was added to the trays in each set of experiment as at (a) and (b) above. About 30 day old rice plants (8 plants/tray) were planted in each of the trays singly in two rows 33 cm long and 11 cm apart as shown in Fig. 2a and b. Granules of carbofuran (10 per cent G) phorate (10 per cent G) and sevidol (carbaryl 4 per cent G + lindane 4 per cent G) were applied separately to 3 trays at random at the rate of 2 kg a.in./ha near the root zone of the first plant in each row. One tray without any insecticide served as a control in each block. After the application of insecticide, adult green leaf-hoppers were caged (10 insects per cage) on each of the plant in the trays by making use of rectangular wooden cages. The cages were extended Ca 3 cm in the soil. The leaf-hoppers on each of the plants were observed constantly to record the time taken (in hrs) for total kill.

b) Diagonal direction : As in the preceeding case two experiments were conducted under flooded and non-flooded conditions separately using randomized block design with 4 blocks and equal number of observations for each of the treatments (insecticides and control). Rice seedlings (IR-8) of 4 leaf stage raised in the nursery, were planted diagonally in each of the trays in such a way that 4 seedlings were located at a distance of 11 cm and another 4 at 22 cm from the centre (c) of the tray as shown in Fig 3a & b.

Granules of carbofuran (10 per cent G); phorate (10 per cent G) and sevidol (carbaryl 4 per cent G + lindane 4 per cent G) were applied at random to 3 trays singly at the rate of 2 kg a.in./ha at the centre (c), leaving the fourth tray without insecticide as



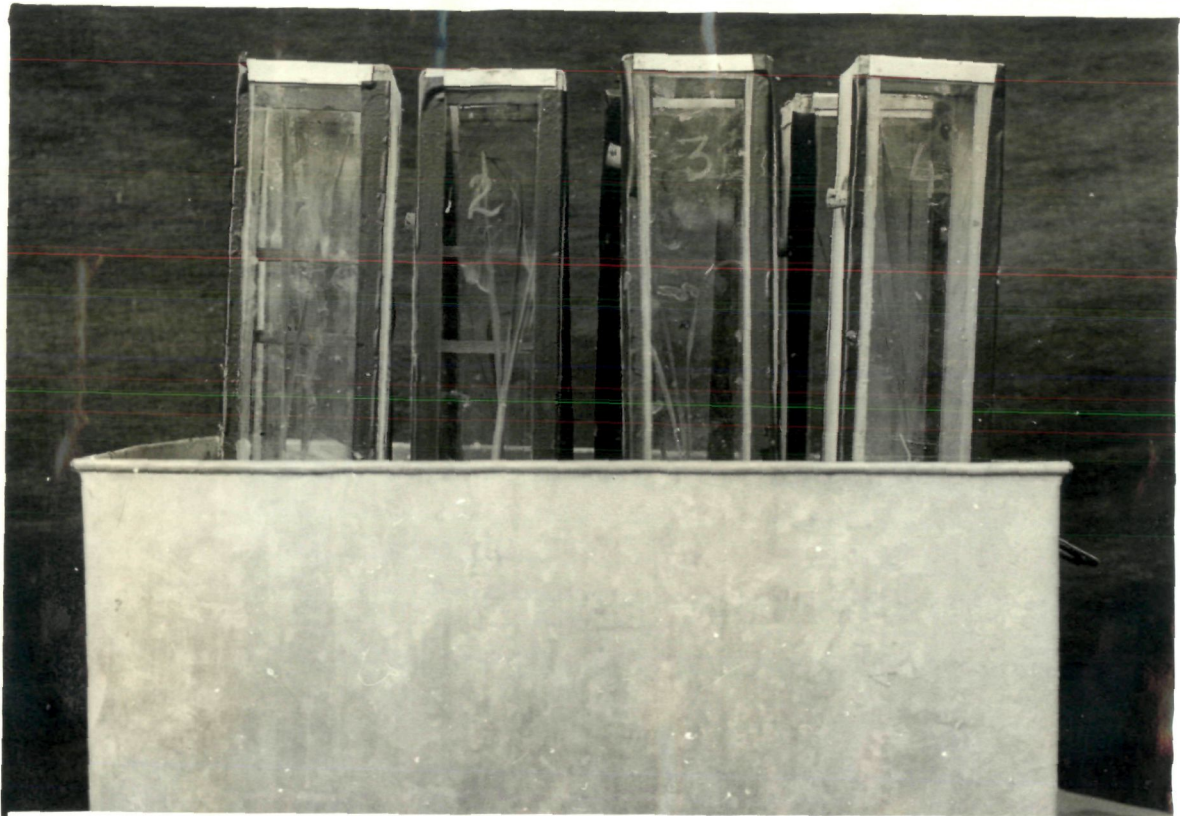


Fig. 2a. Experimental set-up : Movement of insecticide in lateral direction.

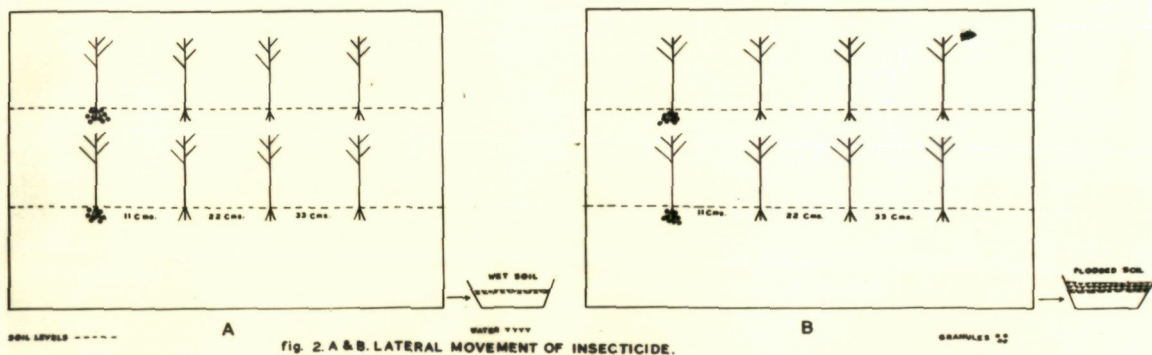


Fig. 2b. Diagrammatic representation : Movement of insecticide in lateral direction.





Fig. 3a. Experimental set-up : Movement of insecticide in diagonal direction.

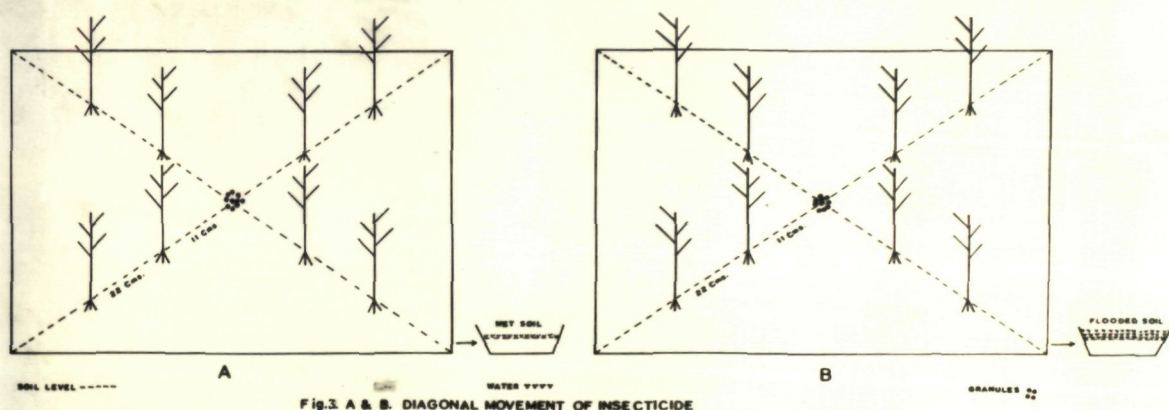


Fig. 3b. Diagrammatic representation : Movement of insecticide in diagonal direction.



control. As before 10 adult leaf-hoppers were caged on each of the plants immediately after the application of insecticides.

### Statistical methods

Combined analysis of data : The data were analysed using the analysis of variance two way classification technique with equal number of observations per cell. Table 1 presents the analysis of variance of the data obtained on plants located at 33 cm under non-flooded conditions from the placement of insecticides.

Table 1 : Analysis of variance : two way classification with equal number of observations per cell.

Source	Degree of freedom	Sum of squares	Mean square	F
Blocks	3	33.50		
Insecticides	2	8457.58	4228.79	8.79 <sup>++</sup>
Interaction between blocks and insecticides	6	121.75	20.29	-
Total	11	8612.83	-	-
Error	12	5773.00	481.08	
Grand Total	23	14385.83	-	-

Similarly analysis was carried out for data obtained on plants located in lateral directions at 33 cms under flooded conditions, 22 and 11 cm under non-flooded and flooded conditions. With regard to



plants arranged in diagonal directions, the data obtained on plants located at 11 and 22 cm from the zone of insecticide application was analysed in this fashion. The average number of hours taken for the movement of insecticides in lateral and diagonal directions was noted on the basis of time required for total insect mortality and tabulated in Tables 3 and 4 respectively.

To study the relationship between the lateral and diagonal movements of insecticide an equation was drawn (Table 5).

#### B. Experiments to check site of retention of insecticides

Butyrate tube cage : For the studies on site of retention of systemic insecticides standard butyrate (plastic) tube cages (size 23 cm x 2.5 cm in dia.) were used for arresting green leafhoppers, N. virescens (D.) on rice seedlings. In order to provide proper aeration inside two windows opposite to each other were made in the wall of these cages and covered with muslin cloth, with the help of an adhesive. The lower portion of the cage was inserted in the soil<sub>A</sub><sup>to</sup> about 2.5 cm depth while the top of the cage was covered with muslin cloth.

Investigations were conducted to study the site of retention of carbofuran (10 per cent G), phorate (10 per cent G) and sevidol (carbaryl 4 per cent G + lindane 4 per cent G) applied to flooded rice plants under glasshouse conditions. For this, two sets of experiments were carried to check the retention<sub>A</sub><sup>in</sup> (A) rice plant and soil and (B) flood water.



a) Retention of insecticides in rice plant and soil :

These experiments were also carried in randomized block with four blocks and equal number of observations per treatment (insecticide). Within a block there were 4 plastic trays (40 cm x 29 cm x 13.5 cm). These were filled with 10.5 cm of strained alluvial soil. Water was added to 2.5 cm level in each tray. Granules of carbofuran (10 per cent G), phorate (10 per cent G) and sevidol (carbaryl 4 per cent G + lindane 4 per cent G) were applied separately to 3 trays of each block, at random with single dose of each insecticide. One tray without any insecticide served as a control in each block (Figs. 4,5). Three doses of each insecticide at the rate of 1, 2 and 4 kg a.i.n./ha were applied in separate experiments.

Every day plants from treated soils were taken out and transplanted separately into experimental pots (12.5 cm x 12.5 cm x 14 cm), containing untreated alluvial soil to 11.5 cm level. Water was added to 2.5 cm in these experimental units. Adult green leaf-hoppers were caged on each plant (10 insects per plant) in the pot by making use of butyrate tube cages (23 cm x 2.5 cm in dia.). The tubes were extended about 2 cm in the soil. The leaf-hoppers on each of the plant were observed every day upto 3 days to record for total kill (Table 6).

In another set of experiment rice plants of IR-8 variety were grown in untreated alluvial soil in similar plastic trays. Soil in 3 trays of each block was treated with granules of carbofuran, phorate and sevidol at random at the rate of 2 kg a.i.n./ha. Fourth tray without any treatment served as control. Rice plants from



untreated soil were taken out every day upto 12 days and transplanted to all the four trays of each block (Fig. 5). Water was added to 2.5 cm level. Green leaf-hoppers were caged on each plant within a butyrate tube cage. The leaf-hoppers on each of the plant were seen to record the number of insects killed on each day upto 12 days (Table 7).

b) Retention of insecticide in flood water : Studies were also conducted to check the retention of granules of carbofuran, phorate and sevidol in flood water using randomized block design with four blocks and equal number of observations per treatment (insecticide). Within a block 4 plastic pots (21 cm x 19.5 cm in dia.) were used. These were filled with 18 cm of strained alluvial soil. Water was added to 2.5 cm level in each pot. Four-leaf stage rice plants of IR-8 variety were planted in each pot and granules of carbofuran, phorate and sevidol were broadcasted separately to 3 pots at random at the rate of 2 kg a.i./ha in the flood water. The fourth pot without any treatment served as control for check. Fresh 4-leaf stage plants were taken out from the nursery and transplanted to plastic pots (12.5 cm x 12.5 cm x 14 cm in height) containing strained alluvial soil to a level of 11.5 cm. Ten leaf-hopper per plant were caged within butyrate tube cage. 100 ml of water from all the four pots of a block were drawn and applied separately to such experimental units. Fresh water was also applied to make the level to 2.5 cm (Fig. 7). The leaf-hoppers on each of the plant were observed on every alternate day upto 7 days to record for the total kill (Table 8).



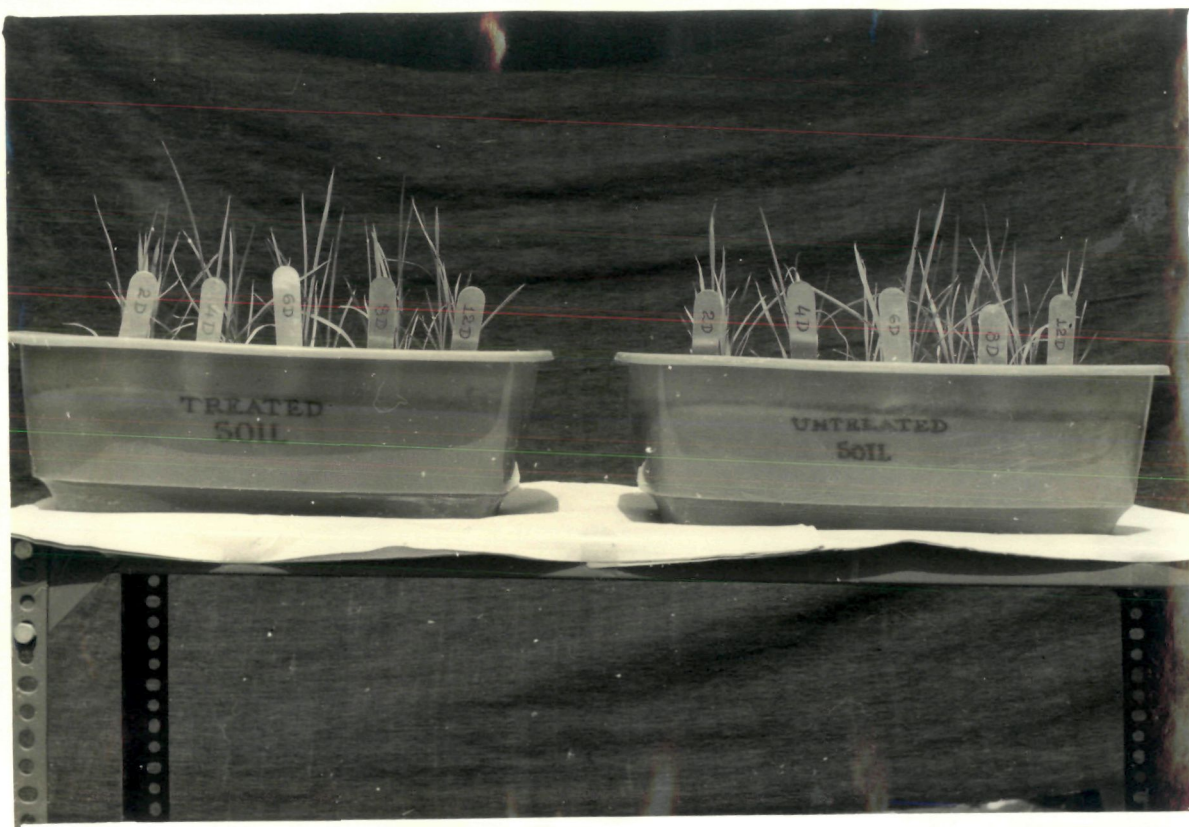


Fig. 4. Rice plants grown in treated and untreated soil.



Fig. 5. Experimental set-up to check retention of insecticide in soil.



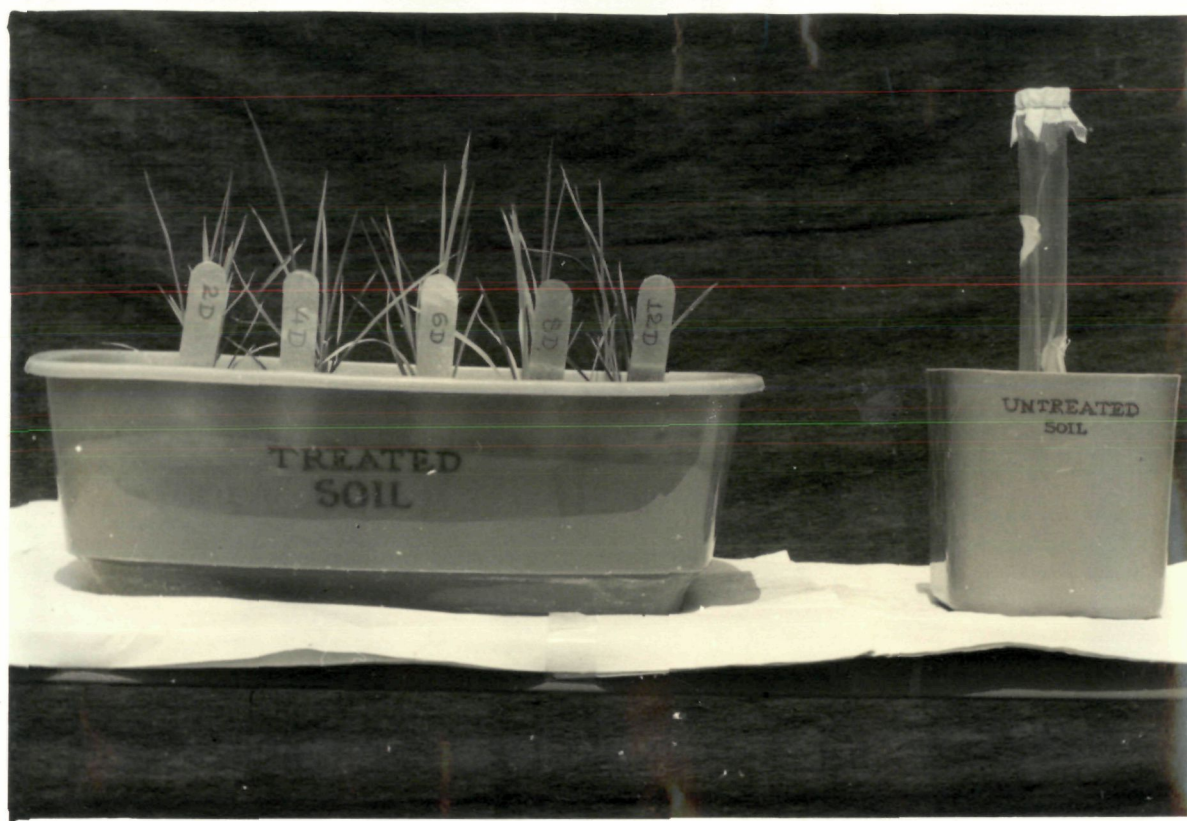


Fig. 6. Experimental set-up to check retention of insecticide in rice plant.

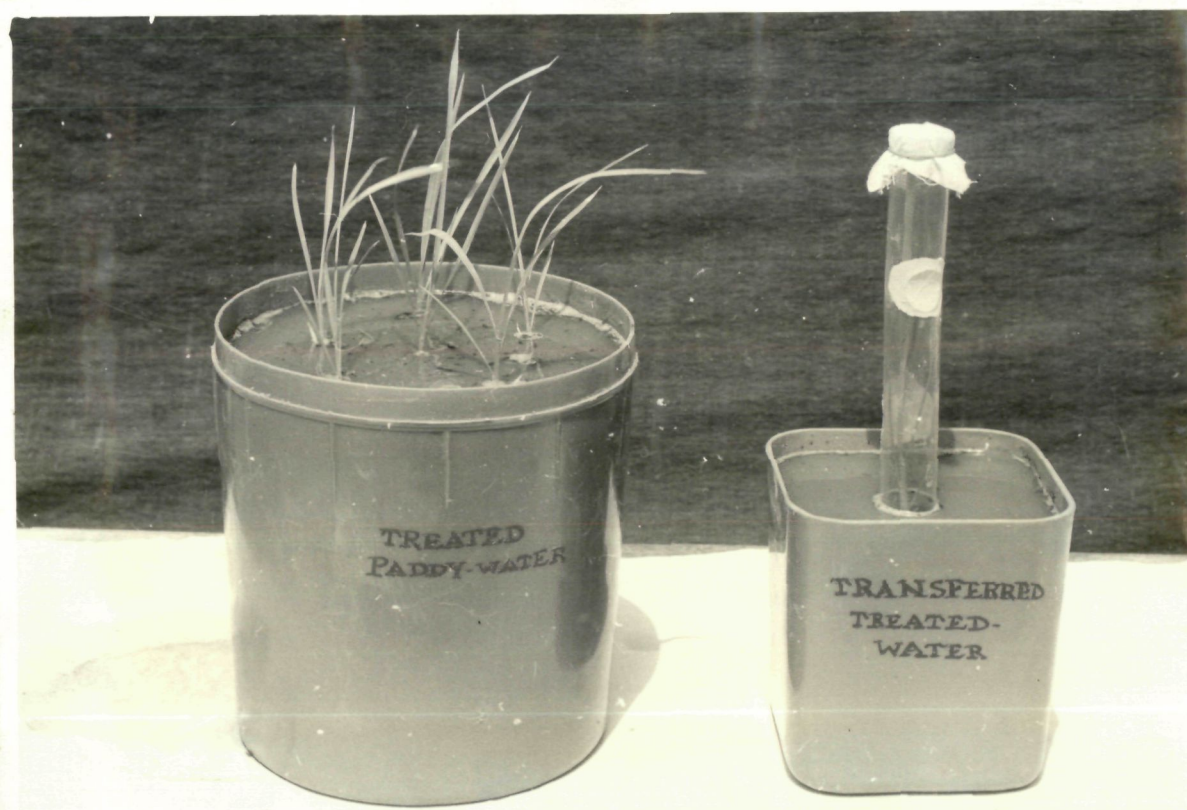


Fig. 7. Experimental set-up to check retention of insecticide in paddy water.



## RESULTS AND DISCUSSION

### 1. Uptake and translocation of insecticides

Data obtained (Table 2) shows that the effective absorption (uptake) takes place within 4 hours of insecticide application. When the soil was kept under flooded conditions the per cent mortality observed was 10, 35 and 8 in case of phorate, carbofuran and sevidol respectively whereas, in moist soil (non-flooded) the mortality of leaf-hoppers was noted 4 hours after treatment, it was seen to be 8, 13 and 5 per cent with the application of phorate, carbofuran and sevidol respectively.

The time required for 100 per cent mortality of insects with the application of phorate, carbofuran and sevidol was 24, 42 and 48 hours respectively under flooded soil conditions and 60, 72 and 84 hours respectively under non-flooded soil conditions. This shows that the uptake of insecticides is much quicker when the soil is flooded with water. While comparing individual insecticides it is noted that absorption of phorate is slower than carbofuran immediately after their applications but to get 100 per cent kill of leaf-hoppers, phorate takes lesser time than carbofuran and sevidol.

### 2. Movements of insecticides

a) Lateral movement : From the analysis of variance (Table 1) it is clear that the interaction between the block and insecticides is not significant and manifestation of the insecticidal activity was not affected by the chance variation that might be obtained in the replication. The F value corresponding to insecticides is  $8.79^{++}$  on

Table 2 : Time taken in hours for % mortality of leaf-hoppers on rice plants.

Insecticide (2 kg a.i.n./ha)	Moisture condition of soil	% mortality <sup>+</sup> observed at different time intervals (in hours) after insecticide application													
		2	4	6	8	12	18	24	30	36	42	48	60	72	84
Phorate	Flooded	-	10	18	23	35	95	100							
	Non-flooded	-	8	15	20	28	55	68	68	68	70	100			
Carbofuran	Flooded	-	35	40	43	50	80	85	90	93	100				
	Non-flooded	-	13	15	25	25	28	60	60	60	68	90	95	100	
Sevidel	Flooded	-	8	15	25	28	43	48	65	78	93	100			
	Non-flooded	-	5	10	15	15	30	40	40	40	55	68	75	90	100

<sup>+</sup> Average of 4 replications.

2 and 12 degrees of freedom and it is highly significant (F on 2 and 12 d.f. at 5 per cent and 1 per cent are 3.88 and 6.93 respectively). It can thus be concluded that the differences between the manifestation of the insecticide measured by the length of time taken for observing total kill of the insects are significantly different.

The average length of time for observing total mortality with the application of phorate, carbofuran and sevidol on plants located 33 cm away from the zone of placement of insecticides under non-flooded conditions are 116.33, 129.12 and 165.00 hrs. respectively (Table 3) for which the standard error is 7.7. A similar analysis carried out for data on plants located at different distances with their standard errors are shown in Table 5. To move to the same distance of 33 cm under flooded conditions phorate, carbofuran and sevidol took 78.25, 82.63 and 99.00 hrs. respectively (Table 3). It is seen that the time required for this movement varied according to the moisture condition of soil, the movement being rapid under flooded soil than in non-flooded soil and this was true for all the three insecticides tested.

b) Diagonal movement : The data on the number of hours taken for total mortality of leaf-hoppers caged on plants arranged in diagonal directions were also analysed likewise. It was observed that the F value corresponding to insecticides was significant whereas the interaction between the blocks and insecticides was not significant and therefore the differences between plants located at the same distance within a block are mainly due to chance variation. As such the results of the four plants located at the same distance for all the replications were averaged out and shown in Table 4. It is seen from the Table that

Table 3 : Time taken in hours for total mortality of leaf-hoppers on rice plants placed in lateral direction

Insecticide (2 kg a.i.n./ha)	Moisture condition of soil	Time taken in hours for total kill of leaf-hoppers at indicated distances from the site of granular application		
		11 cm	22 cm	33 cm
Phorate	Flooded	51.75	62.00	78.25
	Non-flooded	69.62	90.25	116.33
Carbofuran	Flooded	55.45	68.25	82.63
	Non-flooded	82.25	95.75	129.12
Sevidol	Flooded	72.14	87.87	99.00
	Non-flooded	104.50	137.70	165.00

The standard errors in all the cases are found to vary from 6.42 to 15.40

Table 4 : Time taken in hours for total mortality of leaf-hoppers on rice plants placed in diagonal direction

Insecticide (2 kg a.i.n./ha)	Moisture condition of soil	Time taken in hours for total kill of leaf-hoppers at indicated distances from the site of granular application	
		11 cm	22 cm
Phorate	Flooded	44.50	58.92
	Non-flooded	67.50	88.62
Carbofuran	Flooded	56.31	75.75
	Non-flooded	81.00	98.43
Sevidel	Flooded	69.75	82.87
	Non-flooded	99.67	111.22

The standard error in all the cases are found to vary from 5.63 to 11.28



Table 5 : The relationship between the time taken for observing 100% mortality of the green leaf-hopper and the distance from the location (placement) of the granules.

Insecticide	Direction of the movement of insecticides	Moisture condition of the soil				Var. (%)	Equation $Y = (\bar{Y} - bx) + bx$	Var. (%)
		Flooded			Non-Flooded			
1	2	3	4	5	6			
Phorate	Lateral	$Y = 51.28 + 1.53X$	96.77	$Y = 84.58 + 2.44X$	99.46			
	Diagonal	$Y = 27.52 + 1.34X$	96.74	$Y = 53.37 + 1.54X$	99.45			
Carbofuran	Lateral	$Y = 39.90 + 1.38X$	99.62	$Y = 57.46 + 1.96X$	99.13			
	Diagonal	$Y = 38.95 + 1.65X$	99.31	$Y = 62.71 + 1.63X$	99.98			
Sevidol	Lateral	$Y = 37.03 + 1.18X$	96.67	$Y = 54.41 + 1.64X$	97.92			
	Diagonal	$Y = 40.71 + 2.03X$	98.60	$Y = 79.46 + 2.22X$	97.53			

Scale : Y in hours and X in cm.

under flooded conditions the time taken for observing complete mortality of insects on plants located at a distance of 22 cm for the placements of phorate, carbofuran and sevidol are 58.92, 75.75 and 82.87 hrs. respectively. Under non-flooded conditions, the corresponding periods are 88.62, 98.43 and 131.22 hrs. respectively. From these two it is clear that the movement of insecticides in diagonal direction is also faster in the flooded soil than in non-flooded soil.

When the equation was drawn to study the relationship between lateral and diagonal movements of insecticides (Table 5), it was seen that in all the cases the regression of time for observing total kill of the green leaf-hoppers on the distance of the plants from the placement of the insecticide was found to be linear explaining more than 99 per cent of variation. The regression relationships were used to find out the time required for observing total mortality of insects on plants located at any intermediary point within the range tested. With the help of these relationships it is seen that the time required for total mortality increases as the distance from the placement of insecticide increases. Further the time does not depend on the direction in which the plants are located. From this it concludes that whether the plant is kept laterally or diagonally either 11 or 22 cm away from the placement of granules, the time required will depend upon the treatment.

Hence the present studies suggest that the toxicant of each of the insecticides phorate, carbofuran and sevidol moved laterally and diagonally into the root zone and were absorbed by the rice plant. The application of insecticide under flooded conditions enhanced its

uptake and utilization by the plant more well than when it was placed otherwise. A number of studies have also shown that the toxicity of organophosphate, carbamate and organochlorine insecticides to be influenced by the soil moisture (Harris, 1972) and irrigation (Lichtenstein, 1958).

The movement of insecticides in both lateral and diagonal directions was in the order of phorate > carbofuran > sevidol. Massini (1961) studied the movement of 2,6-dichlorobenzonitrile, a herbicide, in soils and in plants in relation to its physical properties. Taking into consideration the water solubility and vapour pressure of phorate, carbofuran and carbaryl + lindane (sevidol) the marked differences in their speed of movement could probably be due to their physical properties. Though phorate was less soluble<sup>+</sup> than carbofuran, its movement was slightly more rapid due to its high vapour pressure<sup>++</sup>. Burt *et al.* (1965) have earlier shown that less soluble and more volatile phorate moved faster in comparison to the other insecticides mainly because it moved through the air rather than the soil water and its vapours reached the roots of the plants much quickly. The slow movement of sevidol both in lateral as well as in diagonal directions could be attributed to the physical properties of its two components : lindane and carbaryl.

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<sup>+</sup>Water solubility

Phorate = 50 ppm, carbofuran = 250-700 ppm, carbaryl = 40 ppm, lindane = 10 ppm.

<sup>++</sup>Vapour pressure

Phorate =  $8.4 \times 10^{-4}$  mm of Hg at 20°C, carbofuran =  $2 \times 10^{-5}$  mm of Hg at 33°C, Carbaryl = 0.005 mm of Hg at 26°C, lindane =  $9.4 \times 10^{-6}$  mm of Hg at 20°C.

Both lindane and carbaryl have low solubility and low vapour pressure. Ehlers et al. (1969a, 1969b) have also described vapour pressure and soil moisture as the factors influencing the diffusion of lindane in soil. Thus it could be concluded that phorate, carbofuran and sevidol moved with the transpiration stream much more faster.

### 3. Site of retention of insecticides

a) Retention of insecticides in plant : It was noted that rice seedlings taken out from soils treated with granules of phorate, carbofuran and sevidol (carbaryl + lindane), each at the rate of 1, 2 and 4 kg a.i.n./ha, and transplanted into untreated soils retained these insecticides for one day. From 2nd day after their transplantation the toxic quantities of the insecticides in transplants were reducing and were almost nil on the 3rd day (Table 6) indicating that the rice plants did not retain the insecticides for sufficient period.

b) Retention of insecticides in soil : On the contrary, transplants from untreated to treated soils (at the rate of 2 kg a.i.n./ha) showed the retention of these insecticides and they persisted for a longer period. The present experiment showed about 80-90 per cent kill of green leaf-hoppers upto 12th day after the soil treatment (Table 7) although phorate and sevin are reported to have residual effect upto 25 and 15-20 days respectively (Pathak, 1964b) and carbofuran upto 20 days (Pathak, 1971) resulting in 70 to 90 per cent kill of leaf-hoppers and brown plant hopper of rice.

Table 6 : Mortality (%) of leaf-hoppers on rice plants transplanted from treated to untreated soil

Mortality checked at indicated No. of Days (D) after transplanting	a.in. kg/ha	Mortality (%) of leaf-hoppers on rice transplants at following insecticide treatment											
		Phorate				Carbofuran				Sevidol			
		0	1	2	4	0	1	2	4	0	1	2	4
1 D		0	100	90	100	100	0	90	100	100	0	70	80
2 D		0	60	50	80	80	0	50	50	70	0	20	30
3 D		0	10	0	0	0	0	10	0	10	0	0	10

Table 7 : Mortality (%) of leaf-hoppers on rice plants transplanted from untreated to treated soil

Insecticide	Mortality (%) of leaf-hoppers on rice plants at indicated no. of days after transplantation											
	1	2	3	4	5	6	7	8	9	10	11	12
Phorate	100	100	100	100	100	100	100	100	100	100	100	90
Carbofuran	100	100	100	100	100	100	100	100	100	100	90	90
Sevidal	100	100	100	100	100	100	100	90	90	80	80	80
Untreated check	0	0	10	0	10	0	0	10	0	0	0	0

Table 8: Mortality (%) of leaf-hoppers on rice plants treated with flood water containing insecticides

Insecticidal water drawn out at indicated No. of days after treatment	Mortality of leaf-hoppers 24 hours after infestation on rice plants treated with following insecticidal water		
	Phorate	Carbofuran	Sevidol
1 Day	80	60	40
3 Days	50	30	20
5 Days	10	0	10
7 Days	0	-	-

e) Retention of insecticides in flood water : The flood water was also checked for its toxicity, under glasshouse conditions. A 100 ml of water from treated soils (2 kg a.i.n./ha) at 1, 3, 5 and 7 days after insecticide application were drawn and applied to rice plants growing in untreated soils. From the mortality of leaf-hoppers caged on these plants, it was found that the toxic quantities of insecticides were retained in flood water upto 3rd day after insecticide application in all cases (Table 8).

Hence from the present study, it was observed that soil retained carbofuran, phorate and sevidol to the maximum and rice plants taken out from such treated soil lost them within 2-3 days. The presence of toxic quantities of these insecticides in flood water upto 3rd day after insecticides application suggest that the flood water should be maintained until the insecticides are absorbed by the soil. As such for proper utilisation and for uptake and for translocation of maximum toxic quantities of systemic insecticides it is felt that flood water should be maintained in the field until the insecticide has dissipated.



### SUMMARY

Studies concerning the uptake, movement and site of retention of three systemic insecticides, phorate, carbofuran and sevidol were made on the basis of the mortality of the green leaf-hopper, Nephotettix virescens (Distant) caged on treated rice plants under glasshouse conditions.

The uptake of the insecticides immediately after their application was observed in the order of carbofuran > phorate > sevidol whereas the time required for total kill of the leaf-hoppers was in the order of phorate < carbofuran < sevidol.

Studies on the lateral and diagonal movements of these insecticides showed that phorate moved faster than carbofuran or sevidol. Further the time required for total kill of the green leaf-hopper was not dependent on the direction in which plants were located but rather upon the type of insecticide, applied (treatment). The effectiveness of all the three insecticides was increased where they were applied to the soil under flooded conditions.

The insecticides, phorate, carbofuran and sevidol were observed to be retained primarily in the soil for about 7 weeks but the plants taken out from the treated soil did not retain the toxic quantities more than twenty-four hours. The insecticides were also found to be present in flood water for about 3 days which suggests that for maximum uptake and proper utilization of the systemics, flood water should be retained in the field until the insecticide has dissipated.

### CONCLUSIONS

1. The uptake of carbofuran, immediately after application was quicker than phorate or sevidol whereas the time required for 100 per cent mortality of the leaf-hoppers was less in case of phorate than in either carbofuran or sevidol treated plants.
2. The insecticides were found to move both in lateral as well as in diagonal direction; the movement of phorate being faster than that of carbofuran or sevidol.
3. Under flooded soil conditions the uptake and movement of the insecticide was much faster than in non-flooded soil conditions.
4. Retention studies showed that phorate, carbofuran and sevidol were retained for a much longer time in the soil and to a certain extent in water than in rice plants.

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<sup>+</sup>Original not seen.